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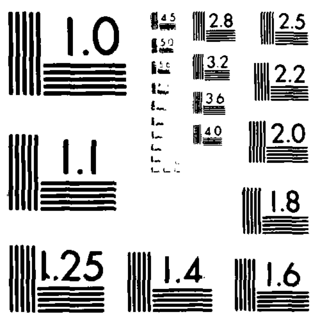

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DAVIDSON LABORATORY

REPORT NUMBER SIT-DL-80-9-2167

November 1980

THE WATER PERFORMANCE OF SINGLE AND COUPLED LVTP-7's, With and Without Bow Plane Extensions

by
Irmin O. Kamm
Jan Nazalewicz

Prepared For:

David Taylor Naval Ship Research &
Development Center
Code 112
Bethesda, MD 20084

Under Contracts:

Office of Naval Research
N00167-80-C-0065
N00014-80-D-0890
NR 062-669

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R-2167

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. [illegible]
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) The Water Performance of Single and Coupled LVTP-7's, With and Without Bow Plane Extension	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER SIT-DL-80-9-2167
7. AUTHOR(s) I. O. Kamm, J. Nazalewicz	8. CONTRACT OR GRANT NUMBER(s) N00014-80-D-0890, N00167-80-C-0065
9. PERFORMING ORGANIZATION NAME AND ADDRESS Stevens Institute of Technology, Davidson Laboratory, Castle Point Station, Hoboken, NJ 07030	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS David Taylor Naval Ship Research & Development Center, Code 112, Bethesda, MD 20084	12. REPORT DATE November 1980
	13. NUMBER OF PAGES Fifty One (51)
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release, Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Amphibious Vehicles
Articulated Vehicles
Coupled Vehicles
Hydrodynamics
Tracked Vehicles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes water performance tests of LVTP-7's in Single and Coupled Configurations with and without Bow Plane extensions. The objective of the tests was to evaluate the improvements in vehicle speed and reduction in bow submergance with speed.

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NR 062-669
(DL Project Numb 11/211)
and
(DL Project Number 48../096)

APPROVED:

Daniel Savitsky, Deputy Director

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ABSTRACT

This report describes water performance tests of LVTP-7's in Single and Coupled Configurations with and without bow plane extensions. The objective of these tests was to evaluate the improvements in vehicle speed and reduction in bow submergence with speed.

KEY WORDS

Amphibious vehicles
Articulated Vehicles
Coupled Vehicles
Hydrodynamics
Tracked Vehicles

OBJECTIVE

The objective of this test program was to quickly evaluate the improvements possible in the water performance of the typical Marine Corps tracked landing vehicle, using the following configurations:

1. *LVTP-7 without modification,*
2. *LVTP-7 with large bow plane,*
3. *LVTP-7 with small bow plane and lip,*
4. *Two Coupled LVTP-7's with bow plane and lip, and*
5. *Two Coupled LVTP-7's without bow plane.*

The investigation of the effects of the bow plane was the main objective. Investigation of the effects of the coupling was secondary.

INTRODUCTION

In 1979 the Davidson Laboratory of Stevens Institute of Technology conducted several investigations for the U. S. Marine Corps Surface Mobility Exploratory Development plan under contract to the David Taylor Naval Ship Research and Development Center. One of the main purposes of these studies was to study possible improvements in water speed, using present tracked landing vehicles, for potential application to future tracked landing vehicle configurations. The biggest impediment in current vehicles to increasing the water speed is the submerging of the vehicle bow into its own wave, even at moderate vehicle speeds. This problem is caused by the constraints of vehicle size and weight distribution, and the resulting form and low freeboard.

Two approaches, checked out on models in the towing tank, showed promise in alleviating the bow swamping problem: one was to add a bow plane, the other was to couple two vehicles and control their attitude in the water. The results are presented in References 1 and 2 respectively. Both configurations promised to allow higher speeds without bow submergence and with good driver visibility.

In order to be able to validate the improvements indicated possible in the model test programs, it was decided to evaluate, quickly, and with a minimum of instrumentation, the merits of these modifications applied to existing vehicles in the field.

For this purpose a quick series of tests were performed at Camp Lejeune, North Carolina by the Davidson Laboratory for the Surface Mobility Exploratory Development Program of NSRDC. This report deals with the field test and evaluation of the two basic vehicle modifications that were found to reduce the submarining problem:

1. *addition of a bow plane, and*
2. *coupling two vehicles.*

Vehicle Description

Three standard LVTP-7 vehicles were used during the test. All vehicles were loaded to the combat equipped condition. There were no facilities available to determine their exact weight or center of gravity location.

1. The vehicle identified as "Y15" was equipped with the bow plane brackets at the front and coupling cylinder brackets

at the rear. "Y15" was used to evaluate performance as a single unit, with and without bow plane. It was also used as the leading vehicle in the coupled configuration.

2. The vehicle identified as "Y19" was used as the rear vehicle in the coupled configuration. This vehicle was equipped with brackets to hold the coupling cylinders and the connecting A-frame which held the two vehicles together.

3. The vehicle identified as "Y18" was a standard vehicle without any modification. This vehicle was used for stand-by and comparison purposes.

Description of the Bow Planes

Three bow plane designs were tested:

1. *54 inch long (large bow plane)(Figures 1 and 2)*
2. *42 inch long (small bow plane)*
3. *42 inch long with a 6 inch lip (Figure 3)*

The bow plane structure consisted of the following hardware:

1. The lower bracket welded to the lower edge of the bow.
2. The bow plane, attached through a hinge to the lower bracket.
3. The upper bracket welded to the top edge of the bow.
4. One or three hydraulic cylinders (depending on the load expected) were used to adjust the angle of attack of the bow plane and to support the plane during testing. The cylinders were independently operated by a hand pump. During the test, hydraulic pressure was monitored.

The total weight of the 54" bow plane and its supporting structure and were conservatively designed and weighed 680 pounds.

Description of the Coupling Mechanism

The coupled pair consisted of "Y15", modified to carry the bow plane, as the lead vehicle, and "Y19", modified to carry the A-frame, as the rear unit.

The coupling mechanism (see Figure 4) consisted of two hydraulic cylinders installed on the deck, one on each side, between the vehicles, using the mounting holes of the mooring cleats. The pitch angle was adjusted by simultaneously contracting or extending these two cylinders.

The frame was used to restrict longitudinal and transverse motion between the vehicles. The lower portion is similar to a standard towing A-frame, attaching to the towing eyes of the rear vehicle and the pintle hook of the forward vehicle. Using a hydraulic cylinder as the vertical brace of the frame, vertical adjustment of the towing attachment was possible. This vertical adjustment was needed to set the proper horizontal vehicle alignment; it also made it possible (quite unplanned) to maintain submersion of the water jets. The design of the coupling allowed the vehicles to roll freely with respect to each other.

The total weight of the conservatively designed coupling system was 870 pounds.

Coincidental with the time of the test, a directive was issued by Headquarters, M.C. not to use the pintle hook for towing purposes. Consequently, only tests in which compressive loads were exerted on the pintle hook were performed. Those tests which

exerted a bending load on the pintle hook were performed with extreme caution.

The thrust deflectors originally intended for the forward unit were incompatible with the vehicles' dual role in the bow plane tests and their mode of installation made it difficult to restore the vehicle to its original condition. As an alternate the steering buckets of the lead unit were to be prevented from fully opening and thereby deflect the thrust outboard. However, this scheme did not work out for mechanical reasons. Subsequently, it was found that the forward jets did not flood over the deck of the rear unit, as it was originally anticipated. Because in these tests the vehicles were not to be steered by articulation, for expediency's sake, all tests were run without deflectors even though a thrust deduction due to hull interference could be expected.

Test Procedure

The LVTP-7 tests at Camp Lejeune were performed at two locations. Speed evaluation tests were run in Court House Bay at the Battalion Maintenance Pier. Open water evaluation tests in comparison with the unmodified LVTP-7 ("Y18") were run in the ocean off Onslow Beach.

The test course layout for the speed tests at Court House Bay are shown in Figure 5. The water surface was generally smooth and the depth varied from 9 to 12 feet depending on tide.

The procedure for measuring vehicle speed was the following:

Each test run was conducted at constant engine speed (RPM) and without steering input.

The elapsed time was measured as the vehicle traversed the premeasured course. Two timers on land and one on the vehicle started timing when the vehicle passed the entering timing station of the test area and stopped when the vehicle passed the exit timing station (see Figure 5).

The driver was instructed not to make any steering correction (which would reduce forward thrust) during the test, the compass heading was recorded and then used to find the angular deviation from the main course. This angle of deviation was then used to calculate the actual distance traveled in the test and the actual speed for each test.

In general, two tests were run in each direction and the final speed reading taken as the average of these 4 runs. However, this procedure could not always be adhered to because one of the test vehicles had a tendency to overheat when operated at an engine speed of 2700 rpm.

In addition, the running and static trims were measured and static freeboard measurements were taken for each test condition (see Figure 6). The trim is that of the deck between the commanders station and the turret, measured with respect to the horizon.

Comparison Ocean Tests at Onslow Beach

These tests consisted of a subjective evaluation of the performance in waves. These tests included:

1. *Side by side comparison runs between vehicles with and without a bow plane*
2. *Maximum speed tests of coupled vehicles*
3. *High-speed water entry of the vehicle equipped with the large bow plane.*

The main purpose of these tests was to obtain a feel for the operation in waves and provide photographic coverage. During the tests, the wave height remained at approximately one foot; the wave period was relatively stable. The tide was going out. Since there was no surf, two runs were made where the vehicle entered the water at high speed, approximately 25 mph, in an attempt to simulate wave loads on the bow plane.

RESULTS

The performance data are presented in the form of graphs. Each data point represents an average of the individual tests taken at the same condition. The data presented consists of:

1. *Vehicle speed as a function of engine rpm.*
2. *Vehicle trim angle as a function of vehicle speed.*

Bow Plane

1. Figures 7 through 10 show vehicle speed as a function of engine RPM for the various configurations tested. All tests were performed in the water-jet mode; that is, with the track drive disengaged. Engaging both track and water jet drive tends to lift the bow up, but also reduces the maximum speed attainable.

   a. Figures 7 and 8 show the standard vehicle performance of "Y15" and "Y18" respectively. Vehicle "Y15" was

modified to accept the bow planes. "Y18" was used to check uniformity of the performance between two "standard" units and subsequently served as the baseline and comparison vehicle.

b. Figure 9 shows the performance of "Y15" with the large bow plane.

c. Figure 10 shows the performance of "Y15" with the small bow plane with and without lip.

The engine speed was torque limited at 2700 rpm regardless of vehicle configuration.

2. Figures 11 through 13 show the vehicle trim angle (deck to the horizon) as a function of vehicle speed:

a. Figure 11 shows trim angle for the standard "Y15"

b. Figure 12 shows trim angles of "Y15" with the large bow plane at three angles of incidence of the bow plane (as defined in Figure 1).

c. Figure 13 shows the trim angle of "Y15" with the small bow plane at an angle of incidence of 30°.

"Y15" was not reballasted after the installation of the bow planes, so that the effects of the weight (680 pounds) added to the bow are reflected in the performance.*

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*All vehicles were tested with a crew of 3, 2 observers and 3/4 to a full tank of fuel (nominally 42,000 lbs.).

Discussion of Results

1. Comparisons of Figures 7 through 10 show that in still water there is a speed increase of about 0.5 mph possible on the basis of the available power. The maximum engine rpm attainable under all conditions with water jet propulsion, was 2700 rpm at full rack. At that rpm the baseline and unmodified vehicle can attain a speed of 7.0 mph whereas the same vehicle equipped with the bow plane can attain 7.5 mph. Differences in speed due to the various bow plane configurations could not be determined with the simple timing method used.

2. The real difference in performance becomes evident when the practical operating conditions for the vehicle are being considered. The standard vehicle begins to experience bow swamping at about 6 mph. At 6.5 mph to 7 mph the swamping is so severe that water spills through the driver hatch (see Figure 14a and 14b). As more water is carried on the bow the running trim becomes increasingly negative as shown in Figure 11. This behavior is in agreement with the results obtained with model tests in Reference 1. Further, the water depth on the foredeck will increase with time to reach the commanders hatch, this behavior is even more pronounced in waves.*

The use of the bow plane results in a bow-up trim with increasing speed, as can be seen from figure 12. In still water, at 20° attitude, the bow plane submerges while at 27.5 and 30° attitude the bow wave was fully suppressed. The small bow plane (with lip) at 30° produced the same effect as the large plane at

*It was reported by the troops that if speed is maintained the whole vehicle will submarine.

30° (See Figure 13). The lip on the leading edge of the small plane was so proportioned as to bring the top edge to the same elevation as that of the large plane. In rough water, waves which spill over the leading edge of the plane will drain away in front of the bow. At no time during the smooth water tests and operation off Onslow Beach did a bow wave build up on the vehicle. All operation was possible with an open driver hatch, whereas the comparison vehicle had to be driven with the driver hatch closed, its vision blocks were under water.

Using driver visibility as a standard of comparison, the real effect was that, in general, a 1 to 1.5 mph greater speed was possible with the bow plane under the conditions tested. Figures 14a and 14b show the build up of the bow wave over the bow at 6 and 7 mph, respectively. Figures 15 and 16 show the bow wave being suppressed at 7.5 mph with the long and the short plate, respectively, set at 30°. Figure 17 shows a side view of the vehicle with the short bow plane (with lip) at a speed of 7.5 mph. Because of the flow pattern caused by the bow plate, the area between the plate and the bow is completely clear of water (See Figure 16).

During the operations at Onslow Beach there wasn't any surf in which the bow plane could be tested. Therefore, several high speed water entry tests were made, in which the vehicle was driven into the water at 25 mph. It was observed that the bow plane easily withstood the force of the impact and was effective in suppressing the bow wave (See Figure 18).* From the hydraulic pressure readings, it is estimated that the impact loading of the bow plane was in the order of 5,000 pounds.

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*A 16 mm movie film covering these operations is available on request.

Coupled Vehicles

The coupled pair consisted of "Y15" modified to carry the bow plane, as lead unit, and "Y19" modified to accept the A-frame as rear unit.

The original intent was to pitch the vehicle symmetrically with respect to each other from a straight and level position, up to an intervehicle angle of 15° as tested in model form in the towing tank (See Reference 2). This means as the forward unit pitches up the rear unit pitches down (See Table 2).

In actual operation, it became quickly evident that at intervehicle angles greater than 5° the operation of the water jets on the rear unit became erratic. At 8° intervehicle angle it was impossible to generate flow through the rear water jets. It appears that the water jet has to be at least half submerged to generate any thrust.

To alleviate this problem the vertical adjustment in the connecting A-frame was used to raise the bow of the rear unit while depressing the stern of the lead unit. By maintaining pitch control with the topside cylinders, a pitch-up attitude could be attained by the lead unit while maintaining a level attitude for the rear unit. The individual pitch attitudes for the various test conditions are listed in Table 2.

Data analysis of the coupled vehicle performance shows a small speed increase of about .5 mph, Figures 19 and 20, compared to the baseline unit (See Figures 7 and 8). The coupled vehicles have the same top speed of about 7.5 mph, with or without a bow plane, with full thrust provided by both vehicles. Figures 21

and 22 show the trim angles of the forward vehicle as a function of vehicle speed at various intervehicle angles, with and without bow plane.

Figure 23 shows the coupled vehicles, with the short bow plane and lip, in the static condition at 0° intervehicle trim. Figures 24, 25, and 26 show the water jet flow pattern at full speed.

The test results indicate that, with a bow up attitude of the lead vehicle, the same speed is possible with or without a bow plane. Observations show that the effect of lifting the bow about 8 inches had the same effect on the bow wave as the addition of the bow plane, thus making the action of the bow plane superfluous. Whether this holds true in higher waves is not known. In general, and on a subjective basis, it was noted that the coupled vehicles experienced much less pitching and rolling in waves.

As was explained in the section on "Vehicle Description" the effects of deflecting the water jets, could not be investigated, as it was originally planned. However, the deflection by the bow of the second vehicle seemed adequate as long as the vehicles were not yaw-articulated. All steering was done using the conventional water jet steering mode, and coordinating the steering inputs by the two drivers.

One test was performed with only the rear vehicle powered. In this condition, there was only a .5 mph speed decrease. If this single test is truly representative it indicates that either the thrust generated by the rear unit is greatly reduced by the jet flow interference by the lead unit, or that the forward jet experiences considerable hull drag on the second vehicle. In

addition, the result would confirm that there is a significant drag reduction when the vehicles are coupled, such as that predicted by the model tests described in Reference 2.

The operation in the open ocean showed that the present "jury-rig" coupling device would present considerable problems with the water entry and exit in waves greater than those experienced on that particular day. Until the motion between the vehicles was stopped by contracting the topside cylinders, and thereby creating a compressive load in the hitching arrangement, there were some anxious moments concerning the warnings issued on the strength of the pintle hook. Once the vehicles were snugged up, and only compressive forces exerted on the pintle, the operation was very smooth and without structural problems. However, in order to snug the vehicles up, personnel had to be topside to work the hydraulic hand pumps. This was only possible because of the low wave height and absence of any surf.

During the "wide open" tests which required an engine speed of 2700 rpm, the engines in both vehicles tended to overheat. An explanation for this behavior has not yet been found.

CONCLUSIONS

Bow Plane

1. The bow plane produces a bow up trim compared to the increasingly negative trim of the baseline vehicle, as maximum possible speed is being approached.

2. The bow plane is effective in depressing the bow wave and prevents the build up of the bow wave on the foredeck and the resulting interference with driver vision.

3. Under the conditions tested, driver visibility is unimpaired up to the top speed of 7.5 mph attainable with the installed power. Without the bow plane, driver vision was impaired at 6 to 6.5 mph.

4. Using all the power available, the baseline vehicle has a top speed of 7 mph. With the bow plane the top speed is 7.5 mph.

5. While the specific size and attitude of those bow planes tested had no measureable effect on top speed alone, it has to be of such a configuration that it suppresses the bow wave. Waves spilling over the plate drain away in the depression caused by the plate.

Coupled Vehicles

1. Coupling two vehicles produces a drag reduction. This provides the option to:

    a. Operate with both units powered, and the water jets as installed, with a gain in maximum speed of about 0.5 mph.

    b. Operate with power from the rear unit only, at .5 mph less and, presumably, with the same fuel consumption as a single vehicle.

2. Coupled vehicles have better driver visibility, because the driver position is elevated and the bow does not submerge.

3. The ride of the coupled vehicle was subjectively judged to be considerably smoother than that of the single vehicle.

4. The operations in the ocean were limited in order not to overload the pintle hook, and because the hardware was not designed for use in water entry and exit, nor for the buttoned-up operation in waves.

RECOMMENDATIONS

Bow Plane

1. Proceed with the development of a prototype bow plane.

2. Make this bow plane retractable and actuated by the crew when operating "Buttoned-Up".

3. Build and install such a plane on an LVTP-7 A1.

4. Perform tests and evaluation in calm water waves, surf and general land operations.

5. Expose the bow plane to normal use in the hands of the troops, record user reaction, guide the design of a production retrofit design.

Coupled Vehicles

1. Design practical deflectors or bucket stops for the water jets and install them on the first unit. Evaluate the loss in propulsive efficiency by:

a. powering the front unit only,
b. powering the rear unit only,
c. powering both units with different water jet deflector settings.

2. Replace manual hydraulic pumps of the coupling system by a powered system which can be actuated and controlled from inside the vehicle.

3. Replace the pintle hook with a fitting which can withstand the reversing loads due to wave action and when entering or exiting the water.

ACKNOWLEDGEMENTS

These tests were conducted under the sponsorship of the Department of the Navy, for David W. Taylor Naval Ship Research and Development Center. The authors wish to acknowledge the guidance received from Mr. Ernest Wolfe, of the System Development Department.

We owe special thanks to the U. S. Marine Corps personnel at Camp Lejeune and specially to Lt. Col. J. R. Williams, C.O. 2nd AAV Battalion, 2nd Marine Division, whose help and cooperation made these tests possible.

The authors also wish to acknowledge the participation of J. Roper Associates, in the design, manufacture, installation and testing of the bow planes and coupling mechanisms; of Mr. Christopher Rau in the test program and of Ms. Mary Ann McGuire in the preparation of the report.

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2. Kamm, I. O., Brown, P. W., and Brady, P. M., Jr., *"An Evaluation of the Coupled LVT Concept,"* Davidson Laboratory Technical Report Number SIT-DL-79-9-2082, November 1979.

SINGLE VEHICLE			
CONFIGURATION	STATIC TRIM	FREEBOARD BOW	FREEBOARD STERN
Without Plane	-.8°	24.5	42.5
Short Plane	-.8°	24.0	40.0
Long Plane	-.8°	23.0	40.5

TABLE 1. Freeboard and Static Trim Measurements of the Single Vehicle With and Without Bow Plane

COUPLED VEHICLES						
	Symmetrical				Assymmetrical	
Intervehicle Trim	0°	5°	5°	8°	0°	2.5°
STATIC TRIM: (Deg.)						
Front Vehicle	-.3	1.5	1.5	4	0	2.5
Rear Vehicle	-.5	-3.5	-3.5	-4	0	0
FREEBOARD: (in.)						
Front: Bow	25	32	33	37	28	33.5
Stern	38	30	29.5	27	37	26
Rear: Bow	27	20	20	16	30	30
Stern	39	46	46	49	36	38

TABLE 2. Freeboard and Static Trim Measurement for Coupled Vehicle Configuration

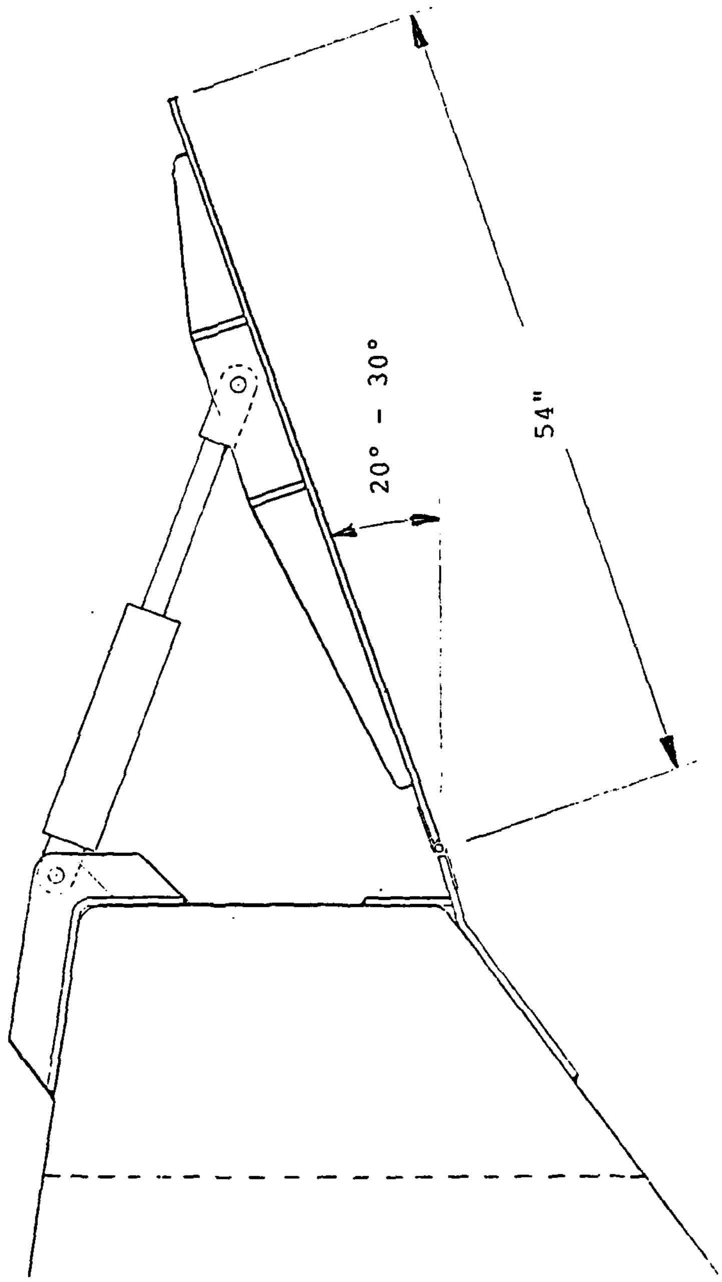

FIGURE 1. Side View of the Large Bow Plane

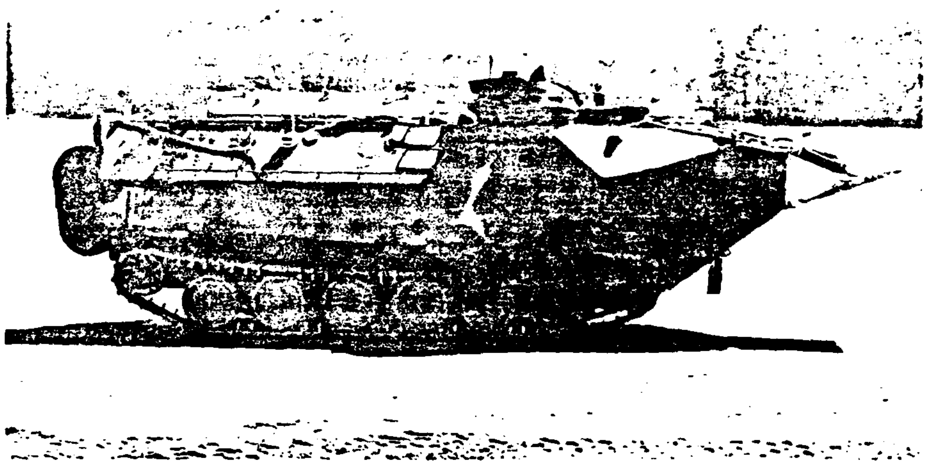

FIGURE 2. Side View LVTP-7 "Y15" With
Large Bow Plane

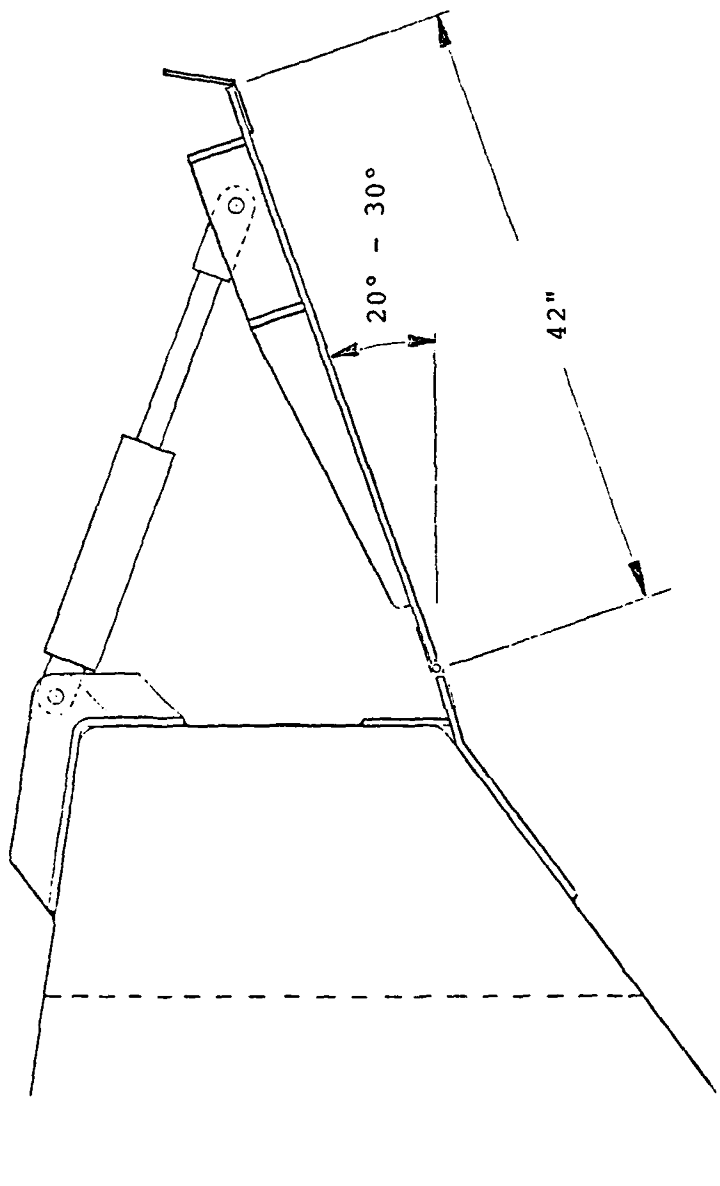

FIGURE 3. Side View of the Small Bow Plane With Lip

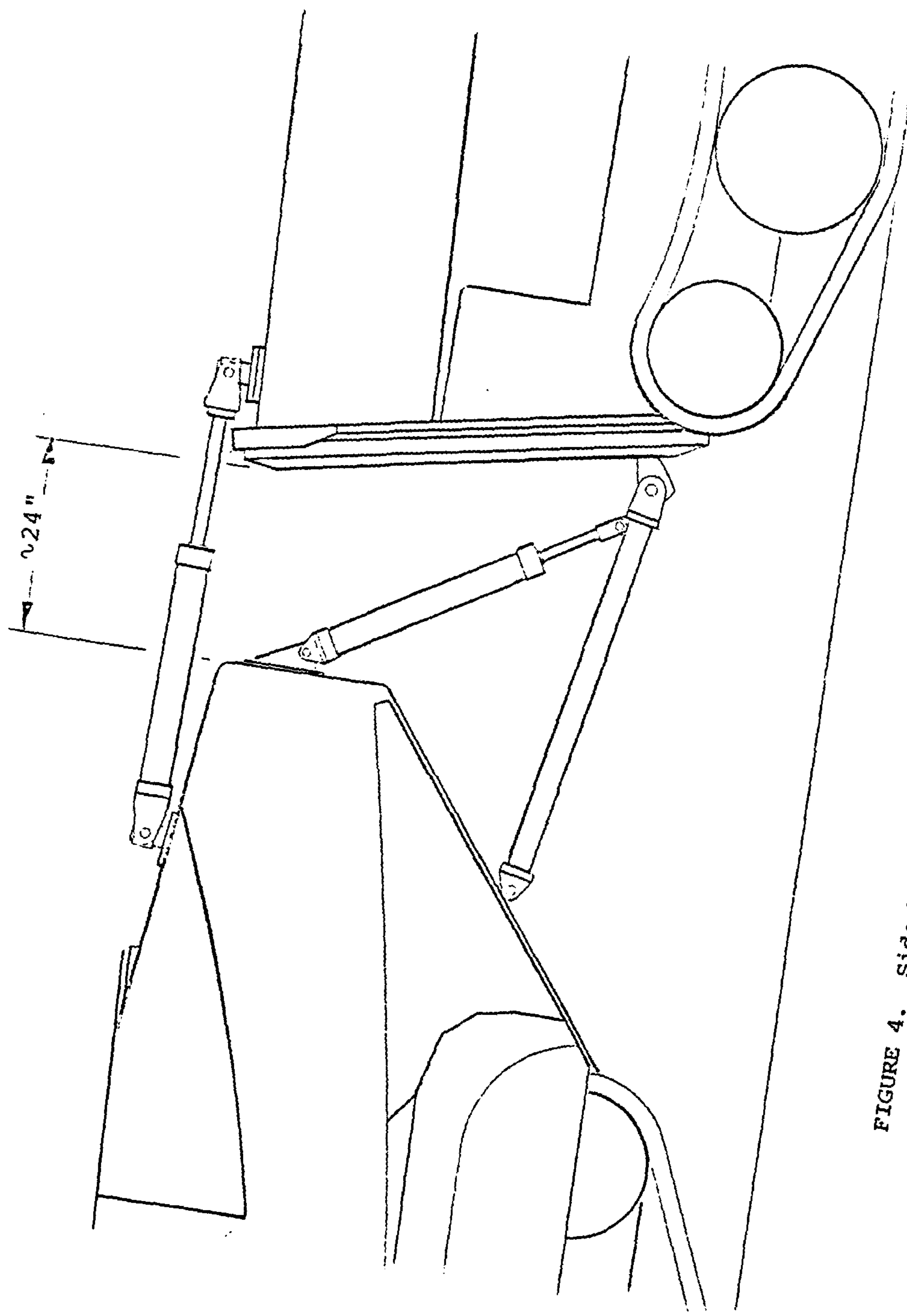

FIGURE 4. Side View of the Coupling Mechanism

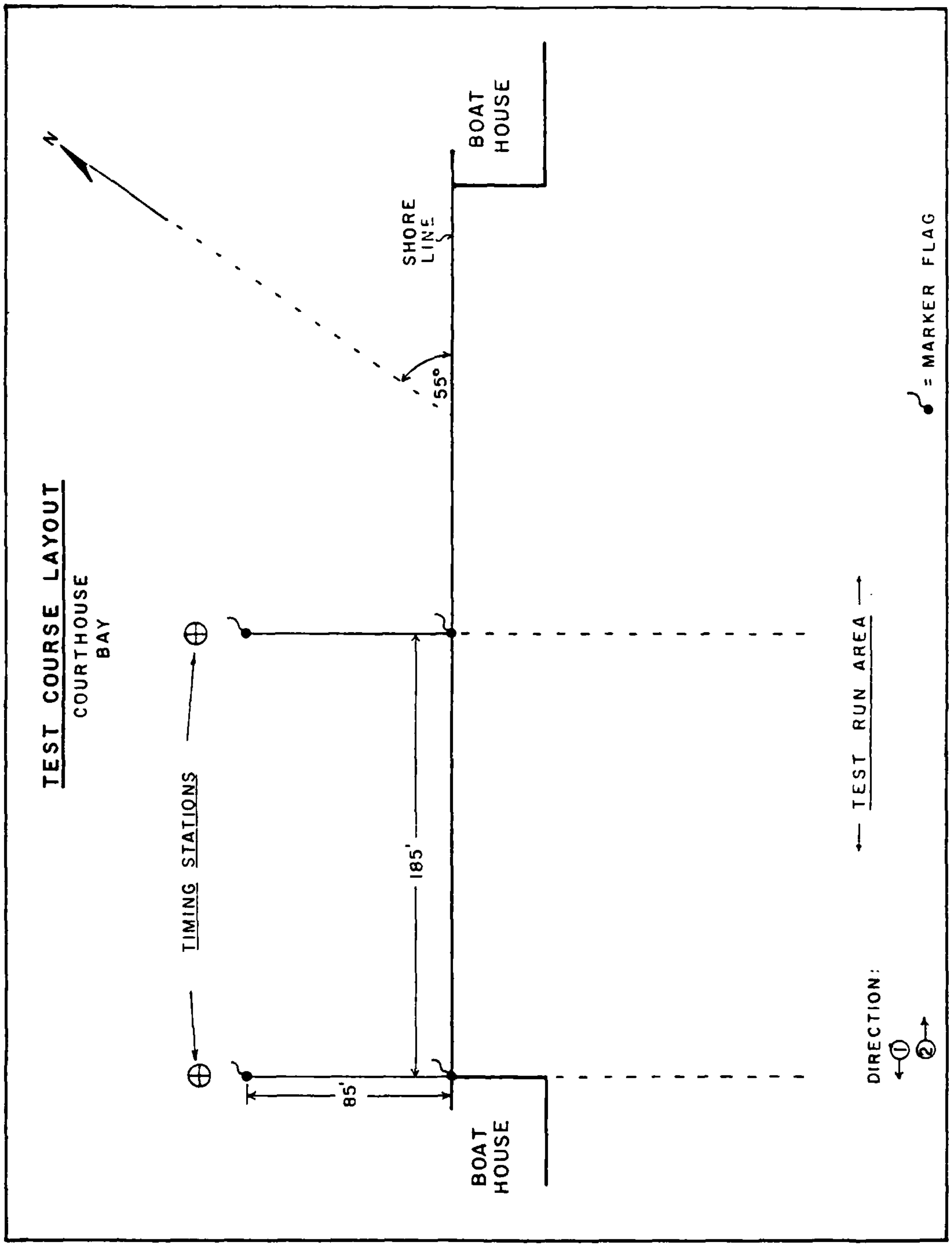

FIGURE 5. Test Course Layout at Court House Bay

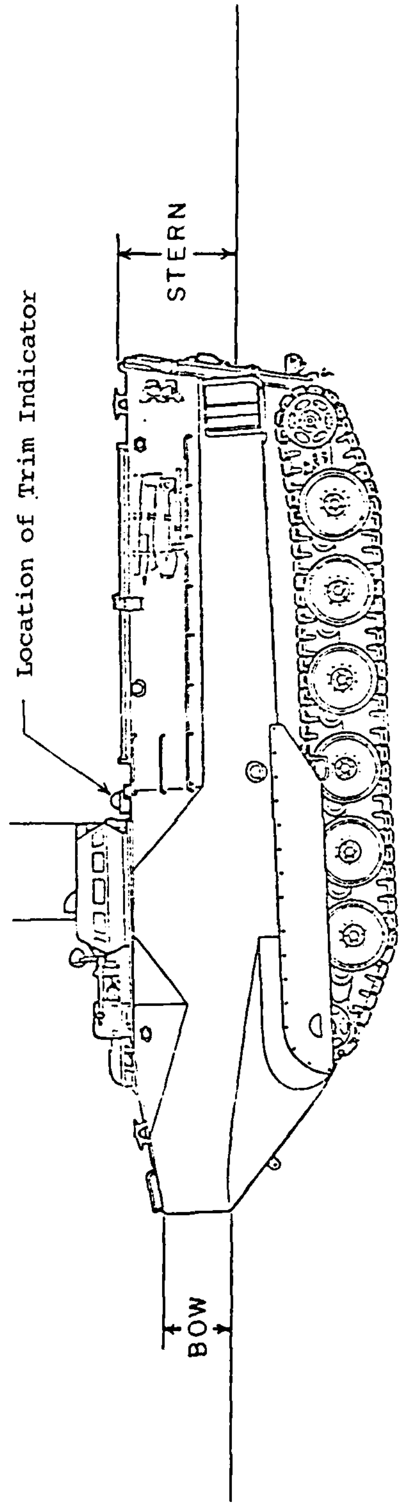

FIGURE 6. Freeboard Measurement Layout

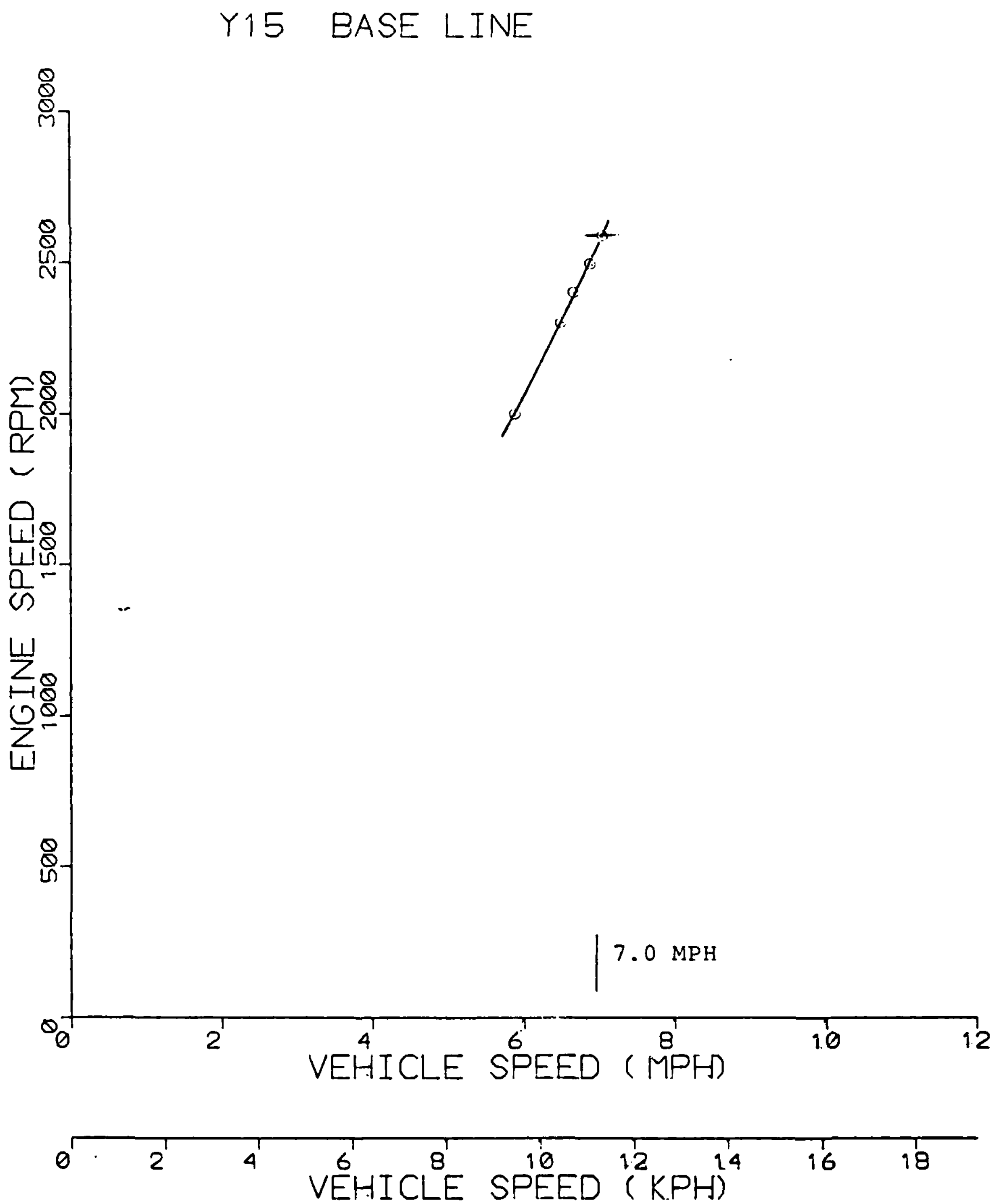

FIGURE 7. Vehicle Speed as a Function of Engine Speed (RPM) for the Single Vehicle "Y15" Without Bow Plane

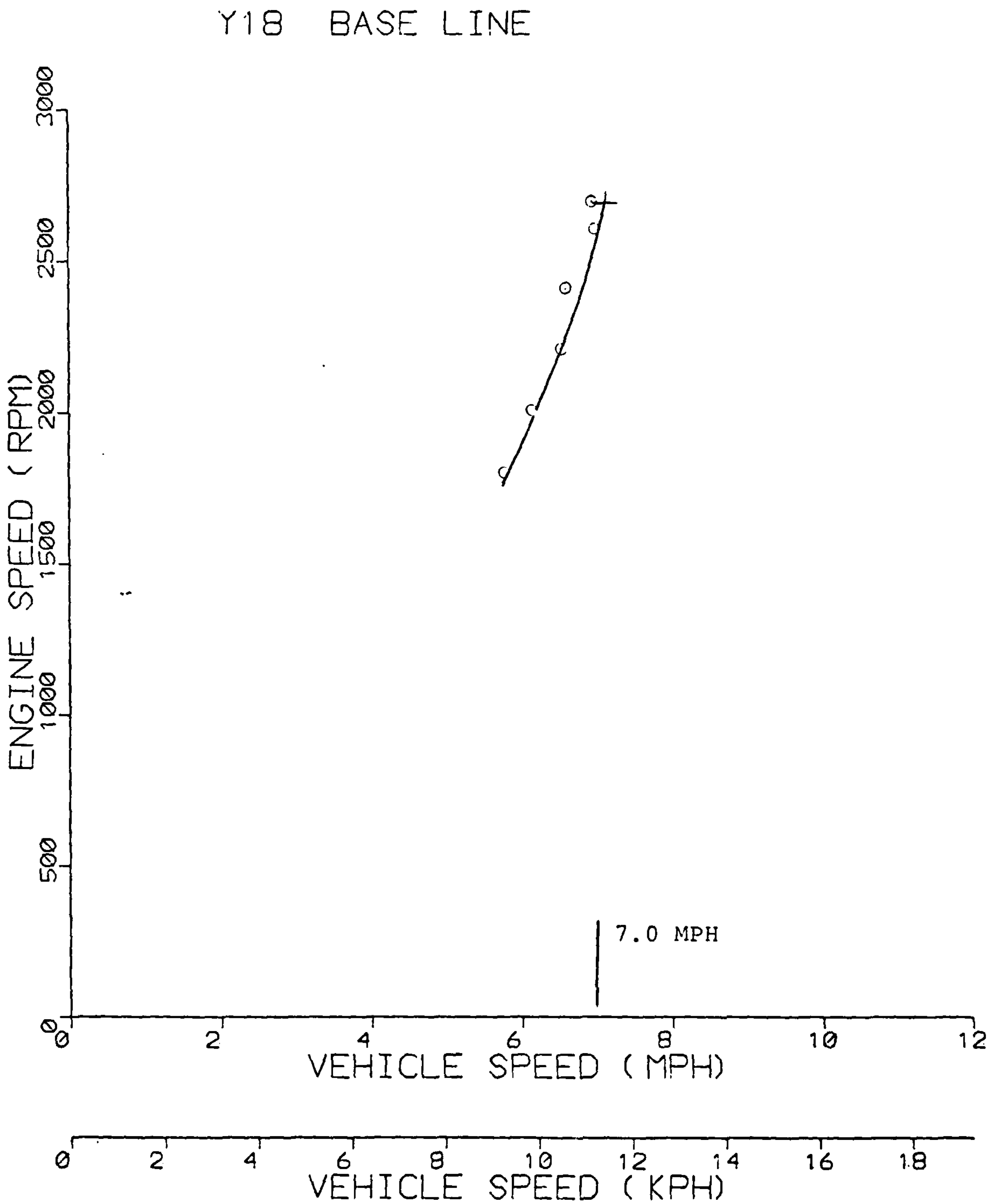

FIGURE 8. Vehicle Speed as a Function of Engine Speed (RPM) for the Single "Y18" Without Bow Plane

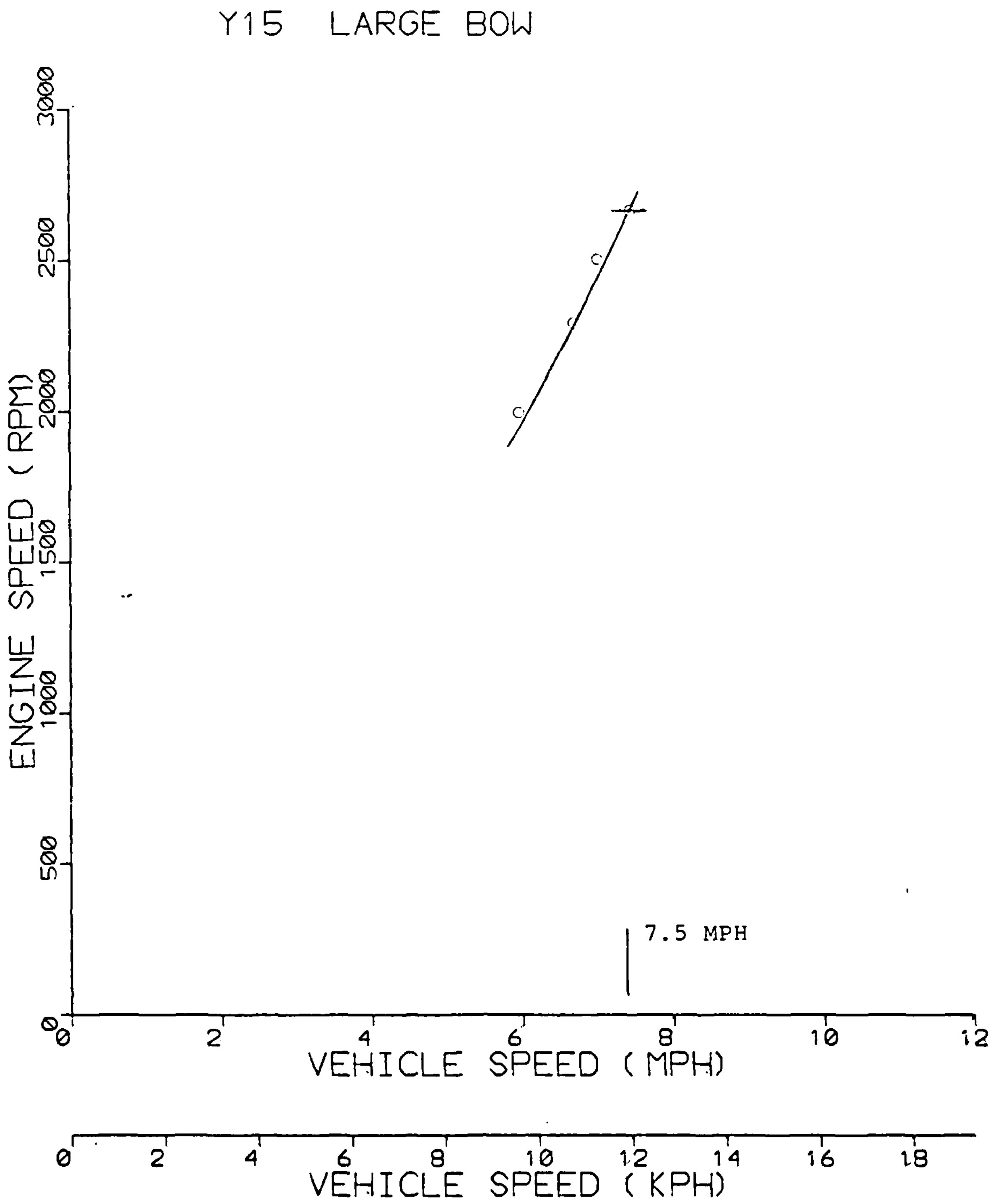

FIGURE 9. Vehicle Speed as a Function of Engine Speed (RPM) for the Single "Y15"

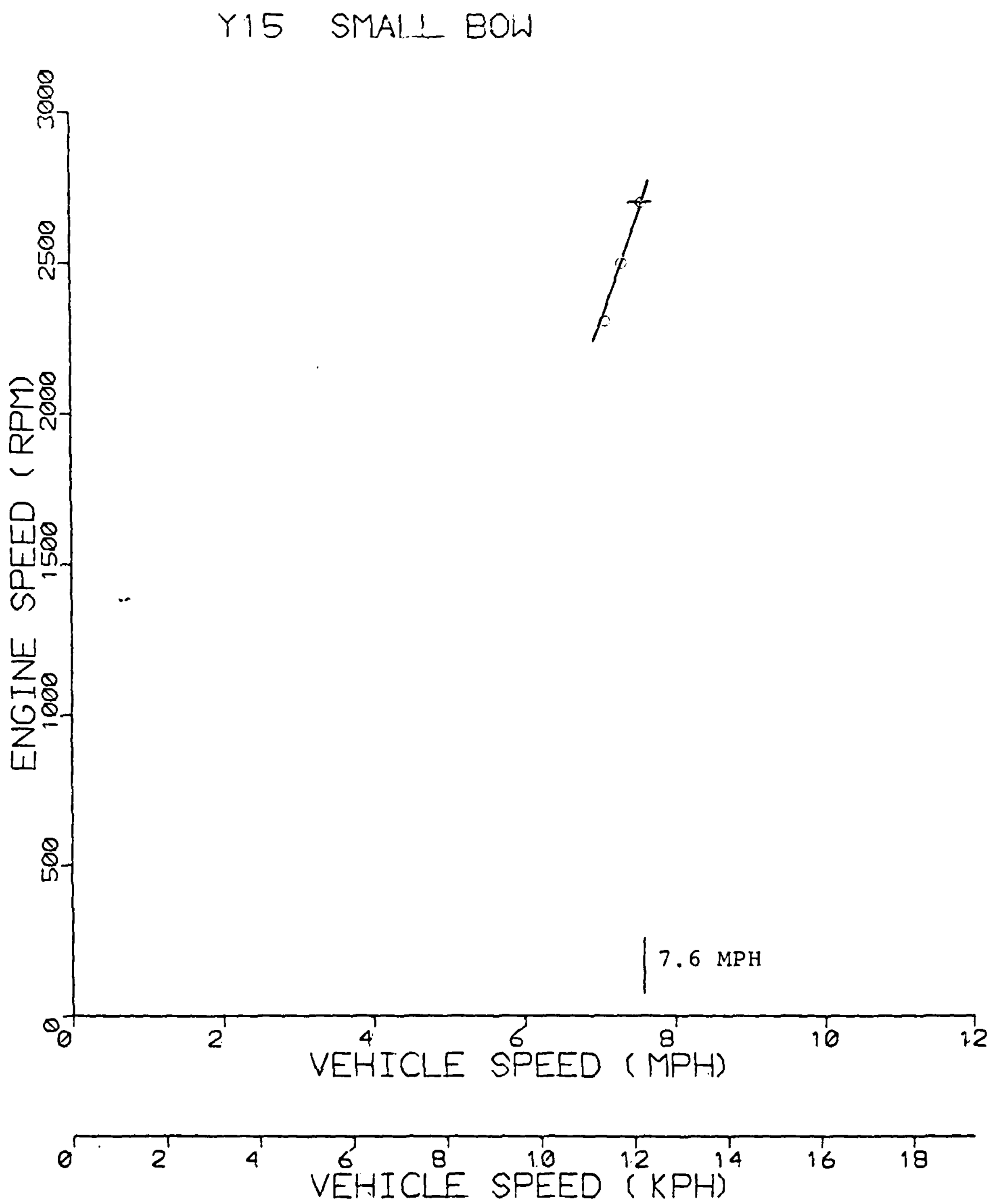

FIGURE 10. Vehicle Speed as a Function of Engine Speed (RPM) for the Single "Y15" With Small Bow Plane

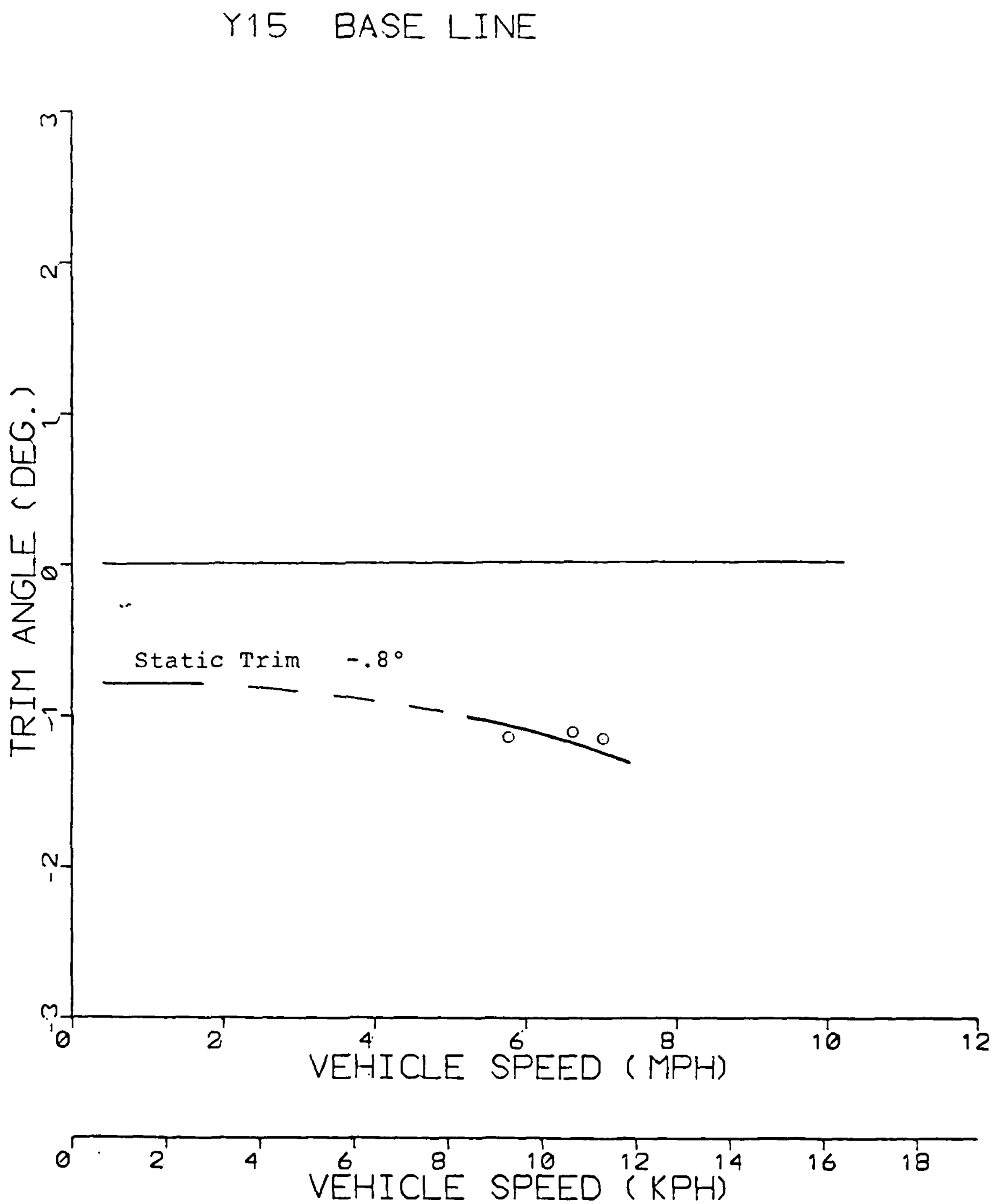

FIGURE 11. Trim Angle (Deg.) as a Function of the Vehicle Speed for the Single "Y15" Without Bow Plane Initial Static Trim -.8°

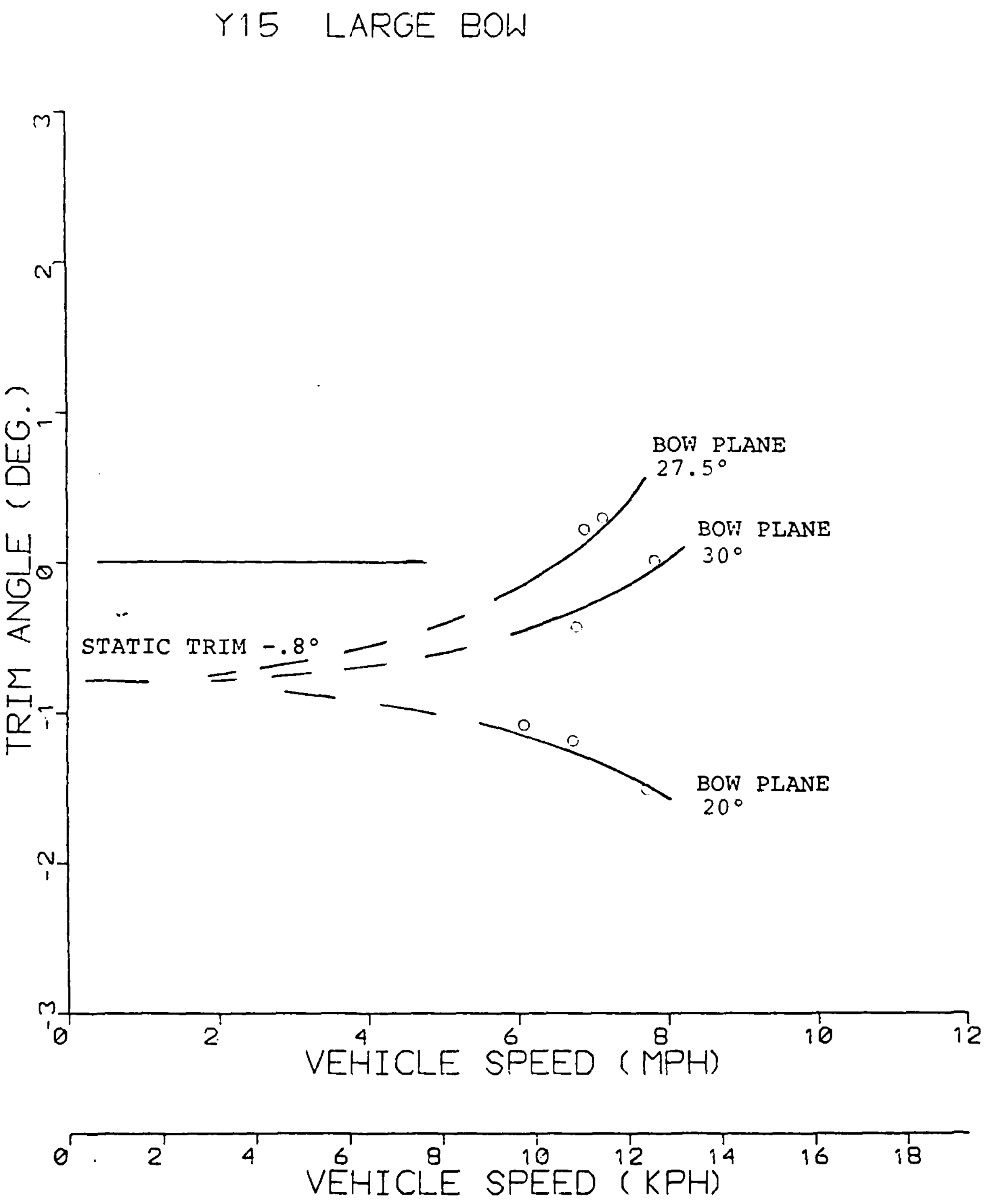

FIGURE 12. Trim Angle (Deg.) as a Function of the Vehicle Speed for Single "Y15" With Large Bow Plane at 3 Different Bow Plane Angles of Attack (20°, 27.5°, 30°) Initial Static Trim -.8°

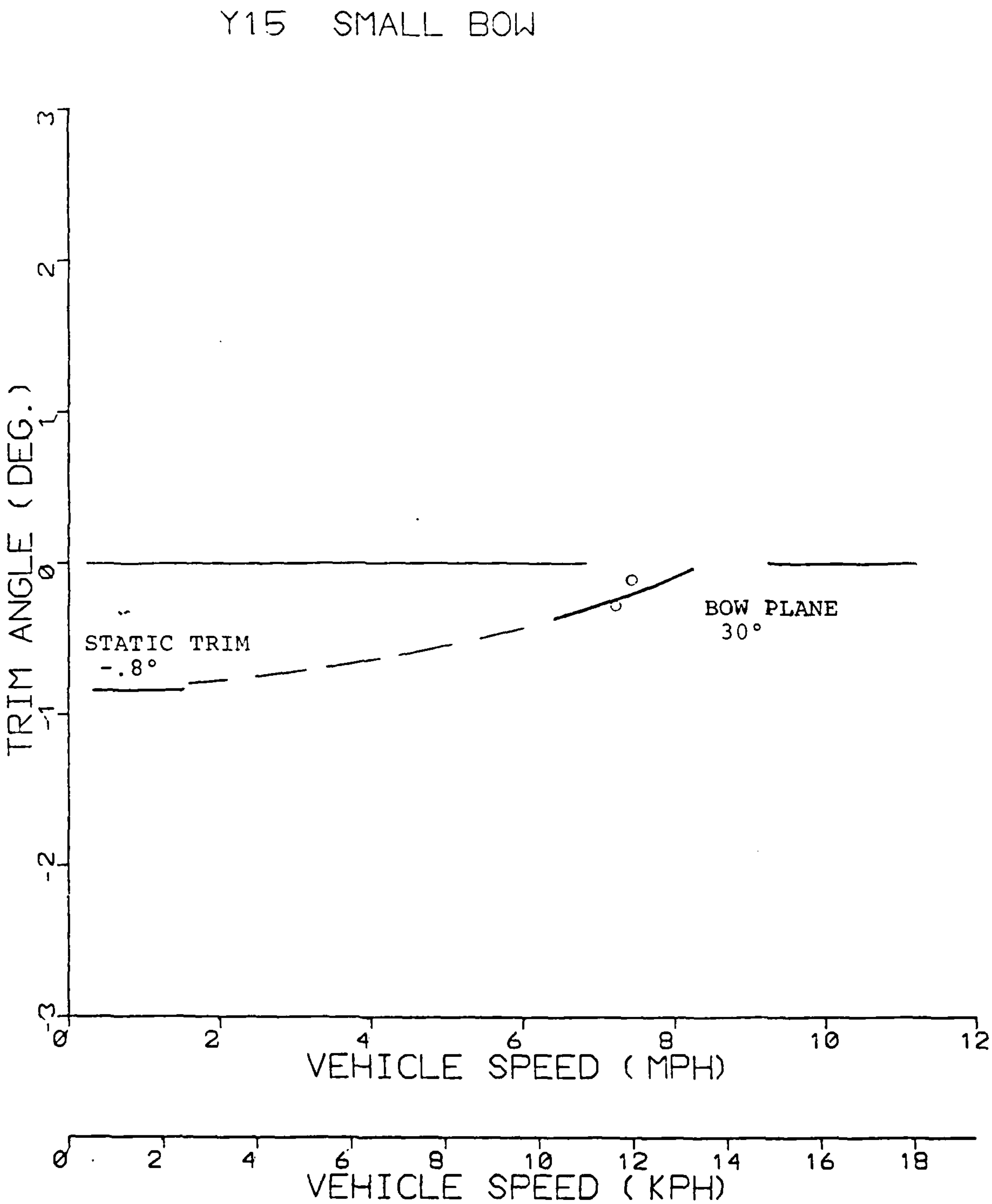

FIGURE 13. Trim Angle (Deg.) as a Function of the Vehicle Speed for the Single "Y15" With Small Bow Plane Adjusted at 30° Angle of Attack. Initial Static Trim -.8°

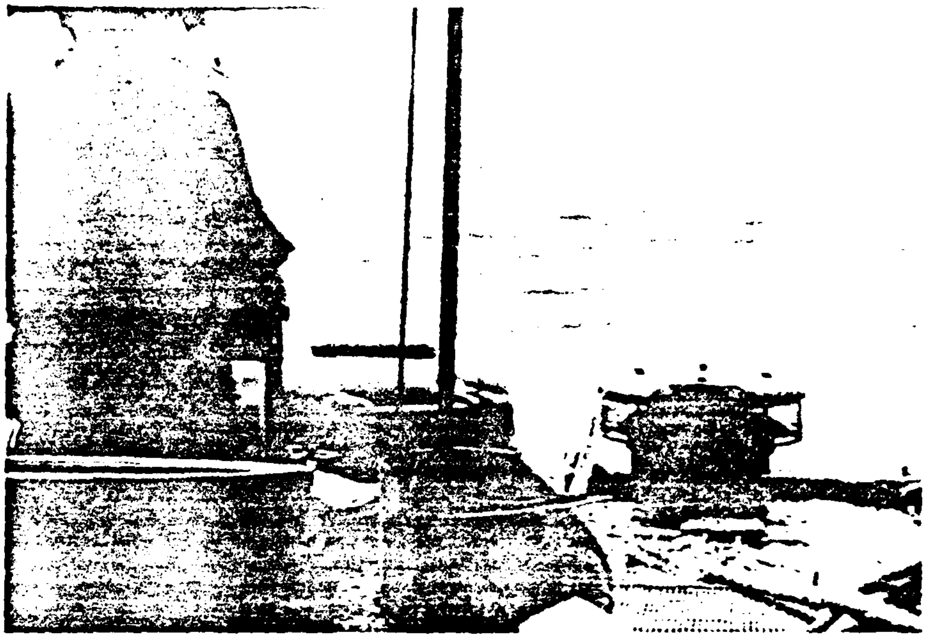

FIGURE 14a. Baseline Vehicle -- Bow Submersion Beginning at About 6 MPH

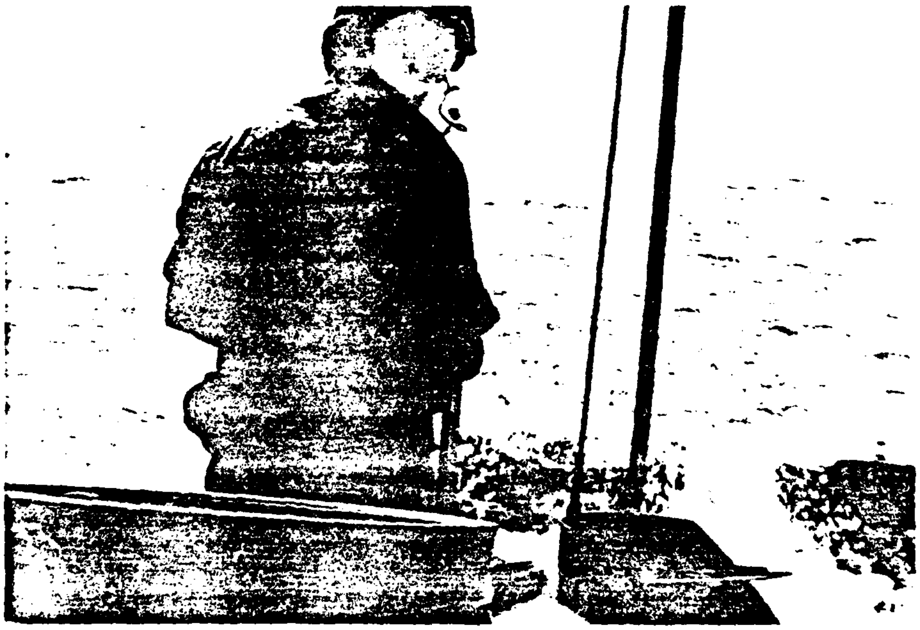

FIGURE 14b. Baseline Vehicle -- Bow Submersion has Progressed Over the Closed Driver Hatch at 7 MPH

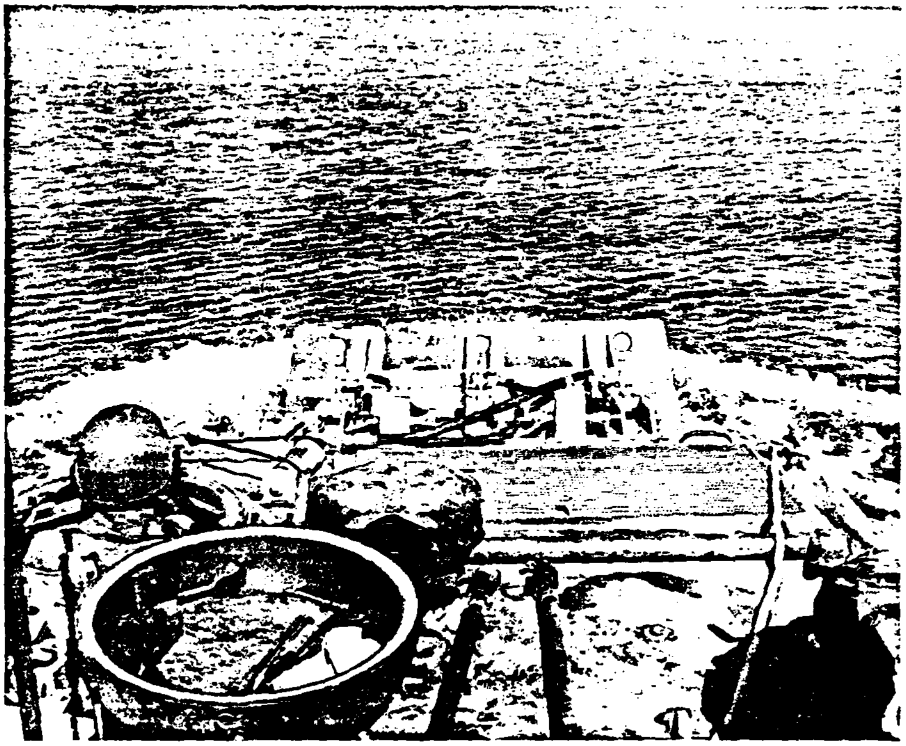

FIGURE 15. LVTP-7 "Y15" With Large Bow Plane
27.5° Angle of Attack, 7.5 MPH
in Still Water

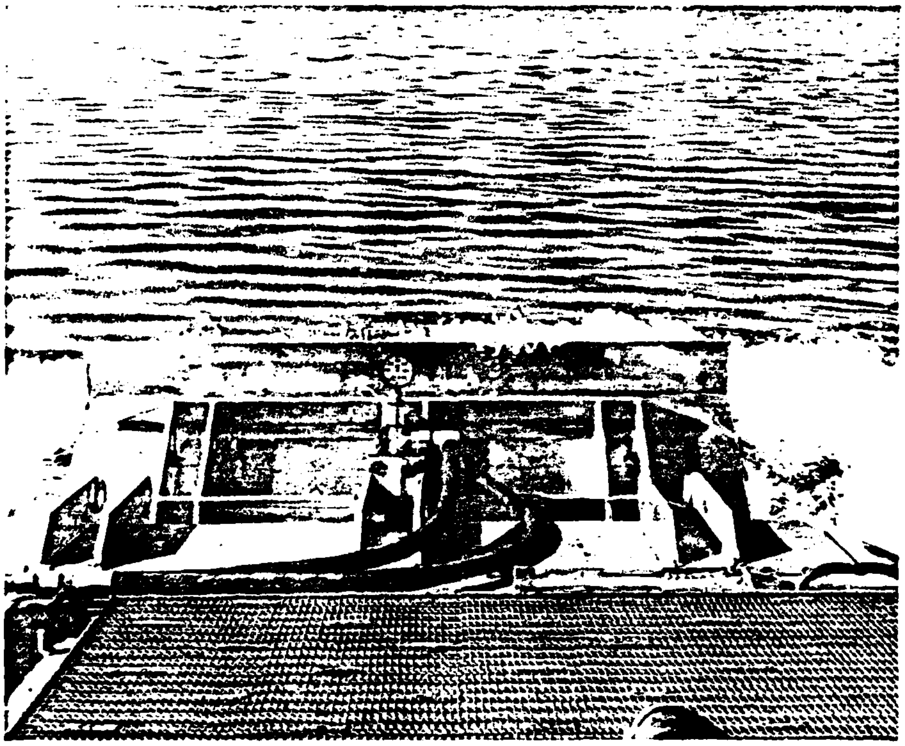

FIGURE 16. View of the Water Flow Around
Short Bow Plane and Lip,
7.5 MPH, in Still Water

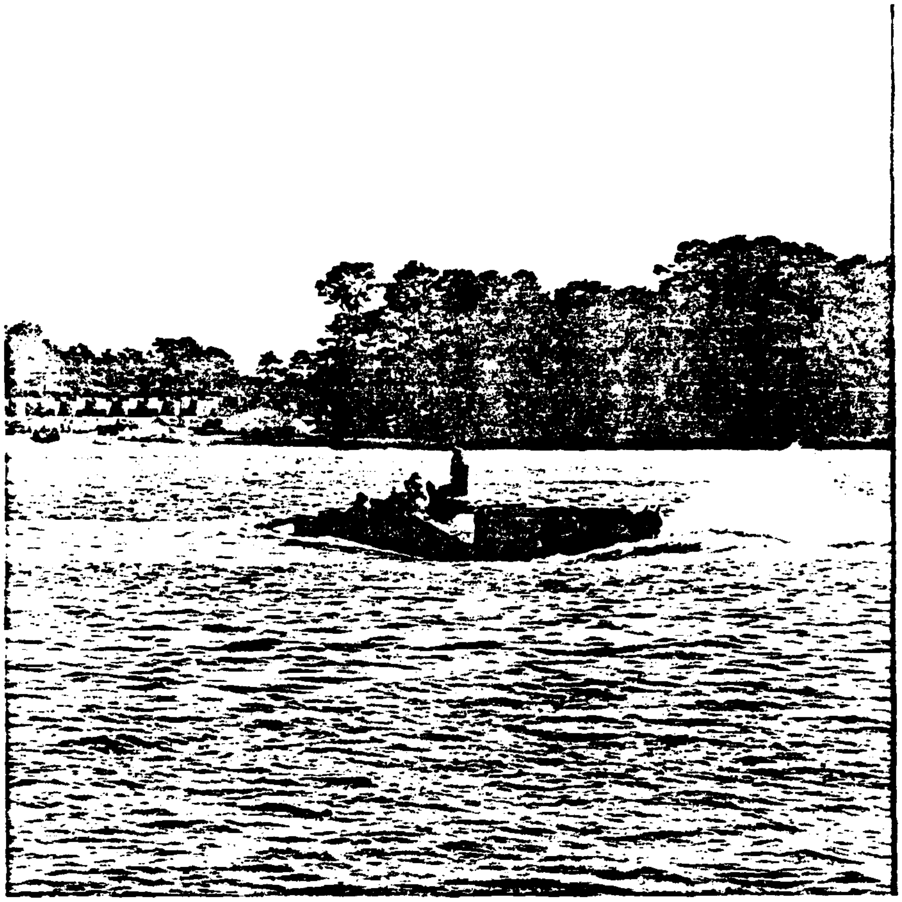

FIGURE 17. Side View of LVTP-7 With Small Bow Plane and Lip, 7.5 MPH in Still Water

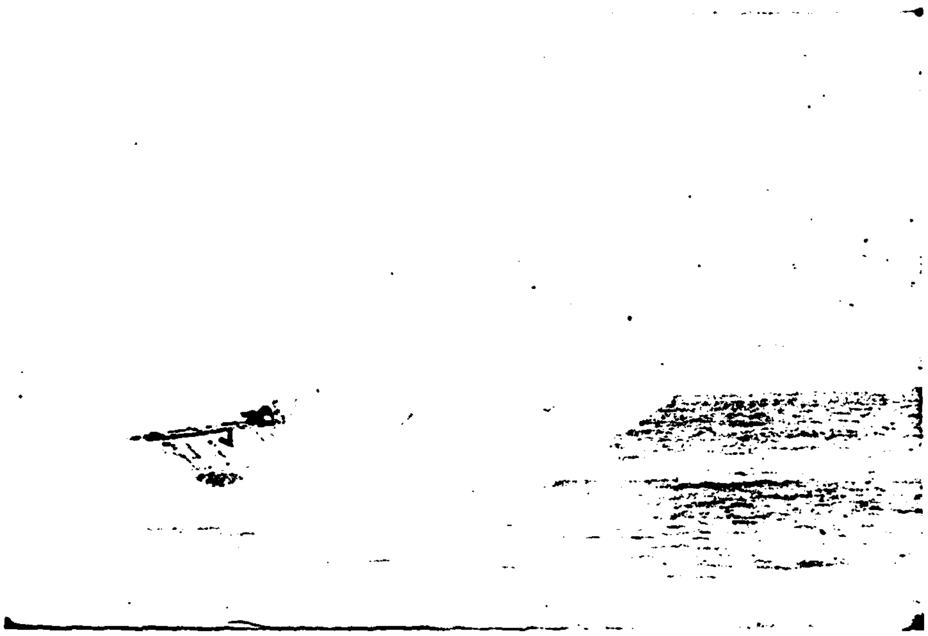

FIGURE 18. High Speed Water Entry
With Bow Plane

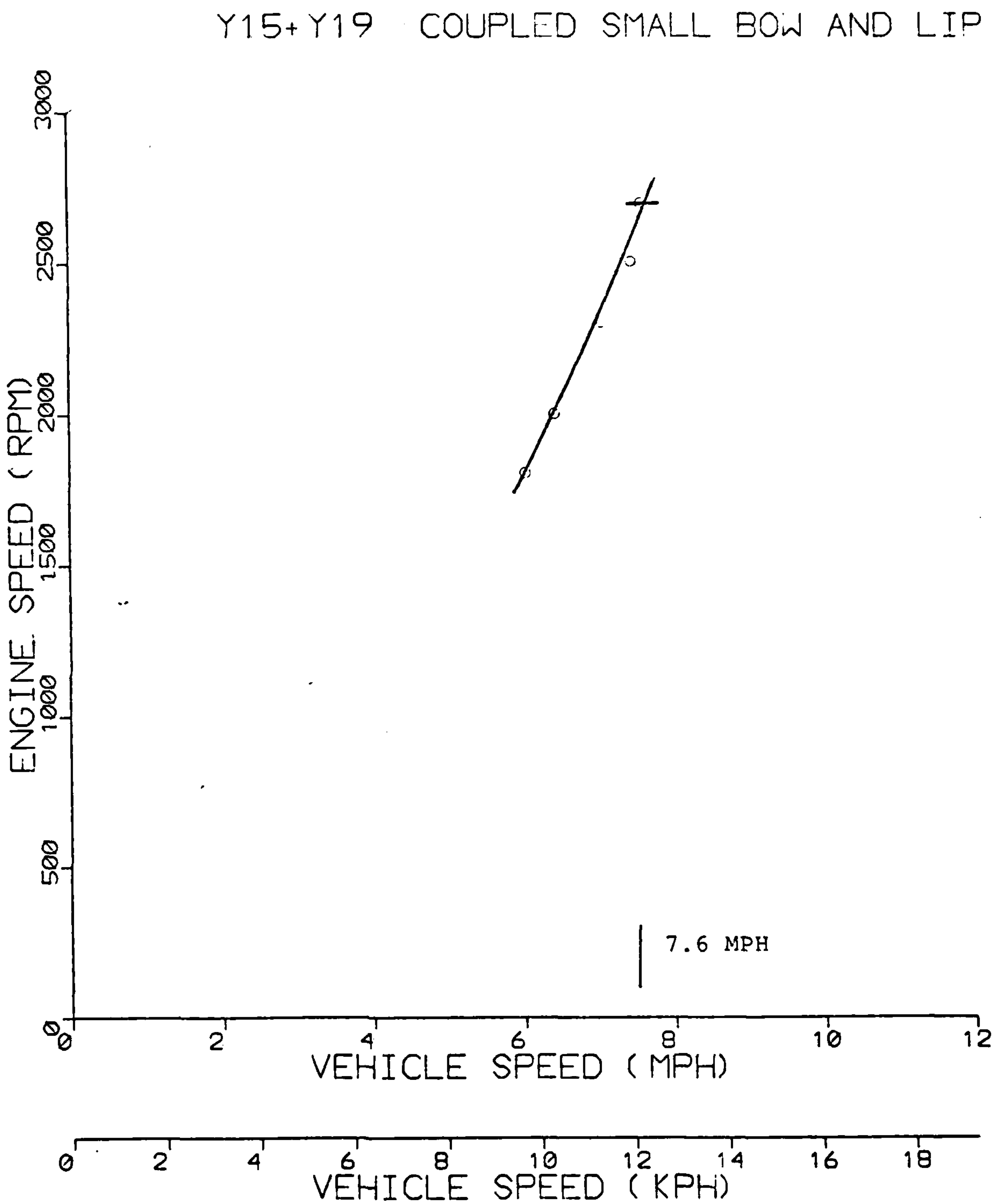

FIGURE 19. Vehicle Speed as a Function of Engine Speed (RPM) for the Coupled Vehicles With a Small Bow Plane and Lip

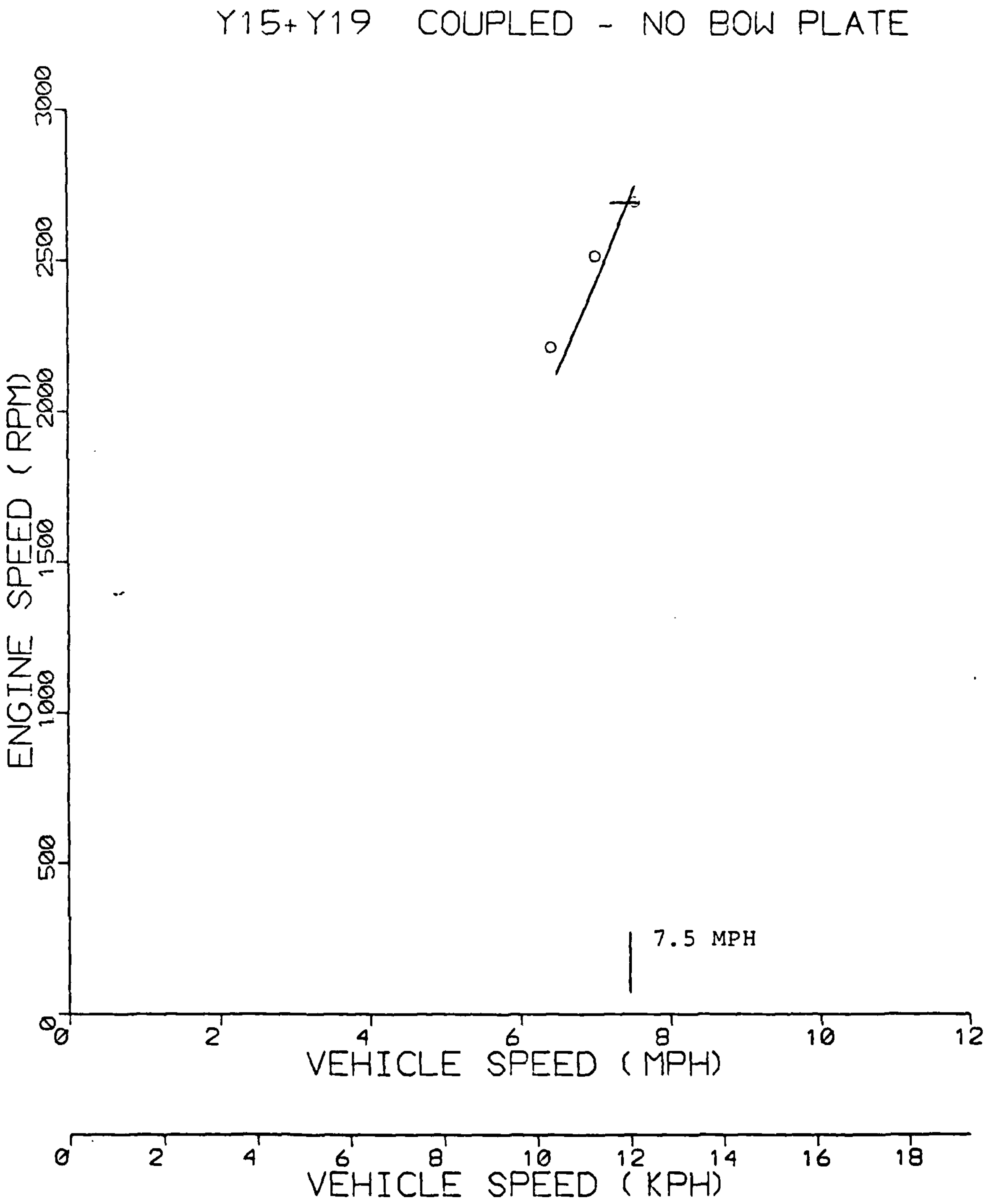

FIGURE 20. Vehicle Speed as a Function of Engine Speed (RPM) for the Coupled Vehicles Without Bow Plane

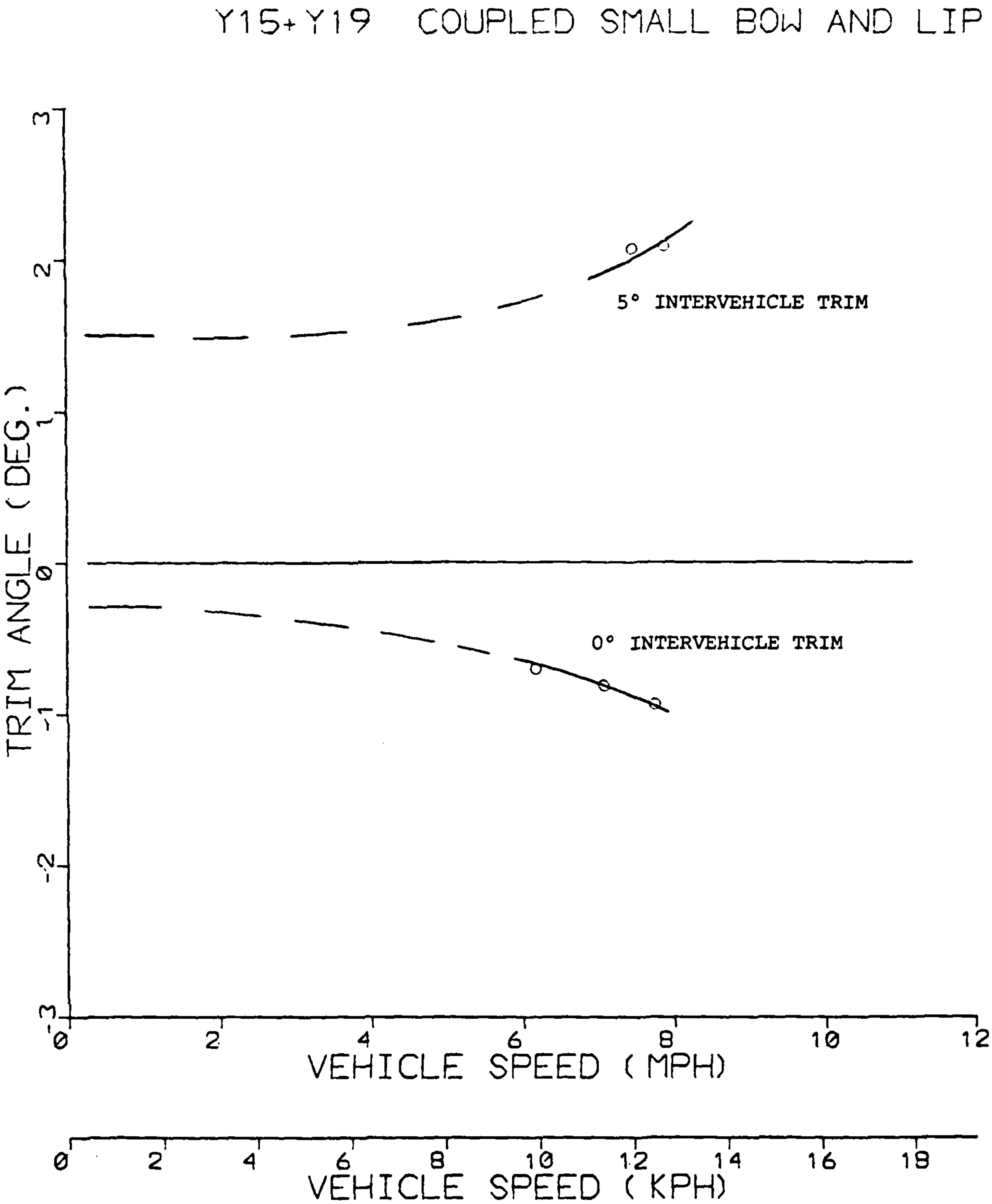

FIGURE 21. Trim Angle (Deg.) of the Forward Vehicle as a Function of the Vehicle Speed for the Coupled Vehicles With Small Bow Plane and Lip at Two Intervehicle Angles

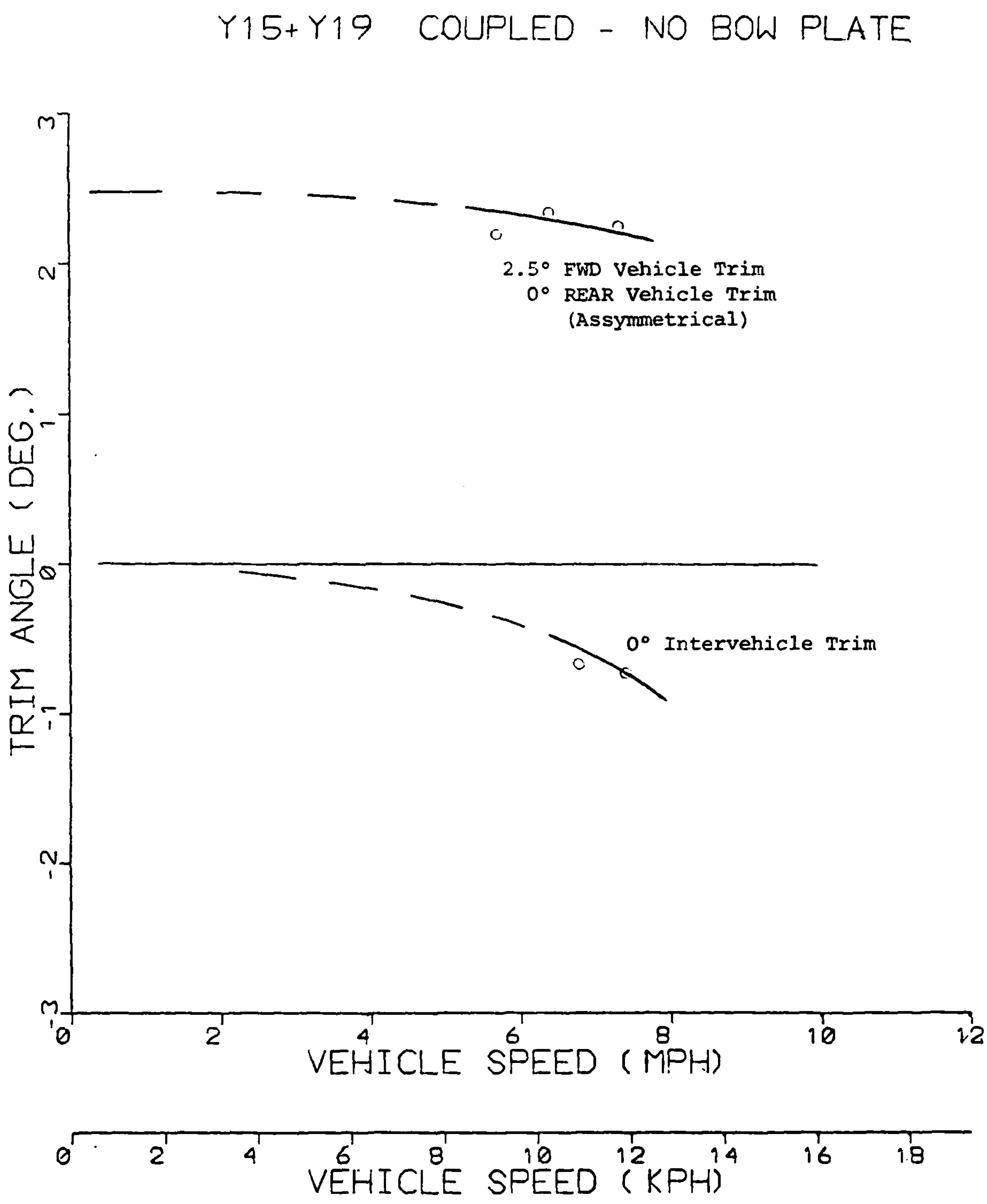

FIGURE 22. Trim Angle (Deg.) of the Forward Vehicle as a Function of the Vehicle Speed for the Coupled Vehicles Without Bow Plane at Two Intervehicle Trim Angles

FIGURE 23. Side View of Coupled Vehicles at Static Condition

FIGURE 24. Coupled Vehicles During Speed Test
With Intervehicle Trim Angle of 5°

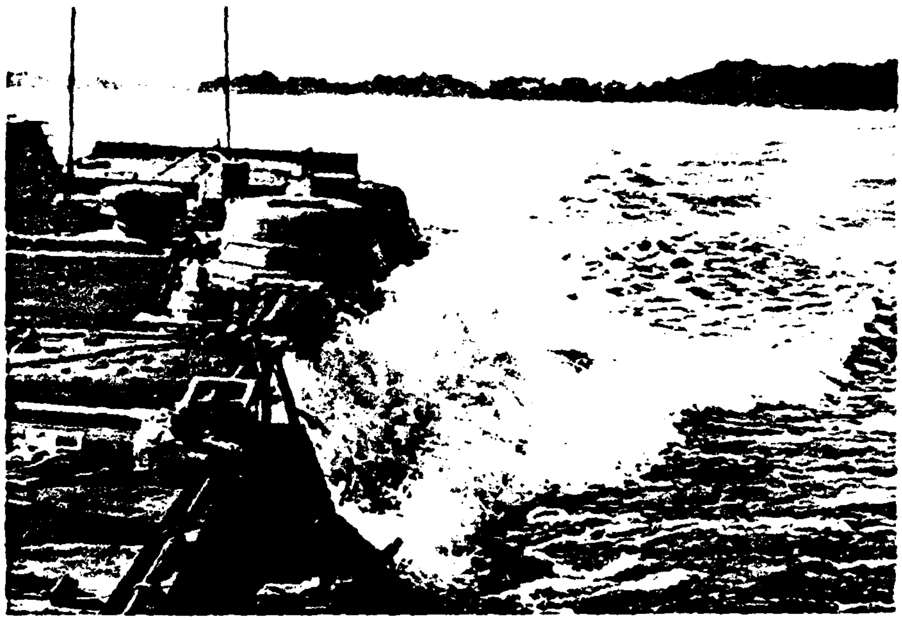

FIGURE 25. Water Flow Around Second Vehicle of Coupled Pair During Speed Test

FIGURE 26. Water Flow Between Two Coupled Vehicles as Seen From the Deck

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